EARLY CARBONIFEROUS SHARK REMAINS FROM THE ROCKHAMPTON DISTRICT, QUEENSLAND

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Teeth of "bradyodont", cladodont and stethacanthid sharks have been found in the Tournaisian-Visean Rockhampton Group. The status of "*Deltodus australis*" Etheridge fil. 1892 is reviewed; this toothplate might be helodont or deltoptychiid. The new material includes petalodont, cochliodont, deltoptychiid, helodont, psammodont and psephodont toothplates which are compared with species from the Early Carboniferous of North America, Europe and the U.S.S.R.

☐ *Carboniferous, sharks, bradyodont, cladodont, stethacanthid, Rockhampton Group, Queensland.*

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Records of Carboniferous shark teeth from Australia are sparse (Long & Turner, 1984). De Koninck (1878, 1898) identified a specimen from New South Wales sent to him by the Reverend W.B. Clarke as "*Tomodus convexus*"; this specimen was presumably lost when Clarke's collection was destroyed by fire in Sydney in the last century (Grainger, 1982). Hardman (1884) referred a tooth from presumed Lower Carboniferous rocks of Kimberley in Western Australia to the genus *Poecilodus*. The whereabouts of this specimen is unknown but shark remains including bradyodont and stethacanthid teeth are now known to be common in the Upper Devonian to Lower Carboniferous Fairfield Group of Western Australia (Thomas, 1957; Turner, 1982a, pers. obs.).

Until a few years ago there was only one Queensland record of a Palaeozoic shark tooth. Etheridge (in Jack & Etheridge, 1892) referred a shark tooth collected by Charles Walter de Vis, then Curator of the Queensland Museum, to a new species, *Deltodus australis*. The single specimen (Fig. 1A, 2A), collected by de Vis during a field trip to the "Agricultural Reserve" near Rockhampton was believed to be lost (Turner 1982b), but it was re-discovered during the move to the new Queensland Museum in 1986. This paper reviews the status of that species and introduces new material collected by Mr Greg Webb (then Department of Geology, University of Queensland; GW = his locality numbers) from the Rockhampton district since 1985; the de Vis specimen is discussed first, followed by short descriptions of the new material. No attempt is made here to review the status of the many bradyodont form and organ genera which are based primarily on teeth (see, Lund 1986). It should be understood that the generic names, and even higher taxa, are used by the author in the same way as multi-element taxonomy is used by conodont workers, or "scale species" used by thelodont workers. These are mostly names of convenience until such time as well-preserved complete fish are discovered. Bendix-Almgreen (1975) argued that the taxon 'Bradyodonti' was no longer acceptable; I follow his usage in this but retain the term 'bradyodont' for teeth which were presumably used for crushing and grinding and which cannot be assigned to a definite family. In recent years new material of fish bearing bradyodont and cladodont teeth has been found in the Carboniferous of Montana (e.g. Lund, 1985; Janvier & Lund, 1985); evaluation of these finds should allow better understanding of the nature and relationships of some of the isolated teeth.

NEW MATERIAL AND STRATIGRAPHY

Thirteen new shark teeth have been obtained from various limestones within the Rockhampton Group on the western limb of the Gracemere Anticline, west of Rockhampton (see Krotsch & Kay, 1977; Day *et al.*, 1983). The Rockhampton Group comprises three formations — the Gudman Oolite, the Malchi Formation and the Lion Creek

Formation (Fleming, 1967) — including extensive beds of sandy oolitic and pisolitic limestone, and calcareous sandstones and siltstones with abundant crinoid, shell and coral fragments. The vertebrate macrofossils are probably relatively common since the new material was found by a single geologist walking over sites without the intention of collecting such fossils. They are usually preserved as black apatite which stands out against the lighter-coloured limestone matrix. One of the shark teeth has been mineralised as pale turquoise-coloured or bluish-pink vivianite. The limestone samples were all treated with dilute acetic acid to remove the teeth and the remaining residues were searched for microfossils, though without success.

Only one of the new specimens was found in an isolated block near the main outcrop; the rest were found *in situ*. In some instances the limestone units containing the teeth are unnamed and the relationship within a measured section of one bed to another is not yet certain. In general, however, the Rockhampton sequence has been ordered and dated using evidence from conodonts (e.g. Druce, 1970; Mory & Crane, 1982). Webb (pers. comm.) is currently studying the coral faunas of the limestones containing vertebrate fossils.

Three teeth have been obtained from the Gudman Oolite, which is the basal, mid to late Tournaisian, formation of the Rockhampton Group (CuI and lower CuIIα of Druce, 1970; *Siphonodella sulcata* zone of Mory & Crane, 1982). These are identified as a helodont tooth, and two possible psephodont and/or cochliodont teeth.

From an unnamed limestone below the Cargoogie Oolite Member (outcrop 20-0 of Krotsch & Kay, 1977) within the Malchi Formation, thought to be low in the Visean (CuII — CuIIIα of Druce, 1970), have come cladodont (stethacanthid) teeth, a psephodont and another fragmentary bradyodont tooth.

From the Lion Creek Limestone Member and other limestones in the Lion Creek Formation (late Visean) come a helodont tooth, a possible psammodont tooth, a deltoptychiid tooth, a petalodont tooth as well as a cochliodont and possible psephodont teeth.

A small vertebrate microfauna which includes xenacanthid teeth, scales of neoselachian and hybodont sharks, as well as palaeoniscoid teeth, has been found in limestones at the top of the Rockhampton Group, which may be equivalent to the Late Visean Baywulla Formation (see Day *et al.,* 1983). This fauna will be examined in detail in another paper.

FOSSIL REMAINS

De Vis' Specimen

Deltoptychiid gen. et sp. indet.
Figs 1A, 2A, B

1892 *Deltodus? australis* Etheridge, in Jack & Etheridge p. 296, pl. 39, fig. 11.
1958 *Deltodus australis* Eth. fil., Hills, p. 93.
1982 *Deltodus,* Long, p. 68.
1982b *Deltodus? australis*, Turner, p. 602.
1984 *Deltodus australis,* Long & Turner, p. 237.

Specimen and Measurements

Queensland Museum (QM) F 809; 32 mm along the occlusal surface, 4 mm deep at broken end.

Locality and Age

The original locality is cited only as "Rockhampton district". In a note (Jack & Etheridge 1892, p. 199) Etheridge stated that in a letter, dated 25th July 1888, de Vis claimed that all the fossils he collected "are from the Agricultural Reserve: from the Fitzroy at Laurel Bank, about 10 miles from Rockhampton, westward to the Nine-mile Lagoon, thence to the Corporation Quarry, Athelstane Range, and to the northern outcrop (at the foot of Bersekers) of the synclinal beneath the township and bed of river". Etheridge gave the age as Permo-Carboniferous Gympie Beds. Hills (1958) then reported the bradyodont tooth as from the Permian "Gympie Series" of Queensland. Long (1982) followed Hills in this placement. De Vis, however, was in no doubt that his Rockhampton fossils were Lower Carboniferous in age, as all were labelled as such in his collection.

Remarks

Etheridge judged that the specimen should be placed in the genus *Deltodus* Agassiz 1859 ms. (see Newberry & Worthen, 1866) based on comparable specimens in the Enniskillen collection from the Early Carboniferous of Ireland. Newberry and Worthen (1866) gave the first formal description of the genus. Their description, however, would cover a wide range of different tooth morphotypes, not all of which would now be referred to *Deltodus*. For the Queensland specimen Etheridge noted only the character of the open and porous structure of the tooth — a clear indicator of the tubular dentine typical of many so-called bradyodont teeth. He also described the cross-section of the tooth as "semi-circular, abruptly so on the outer side". Etheridge remained in doubt, however, as he wrote "I do not feel at all certain that the reference to

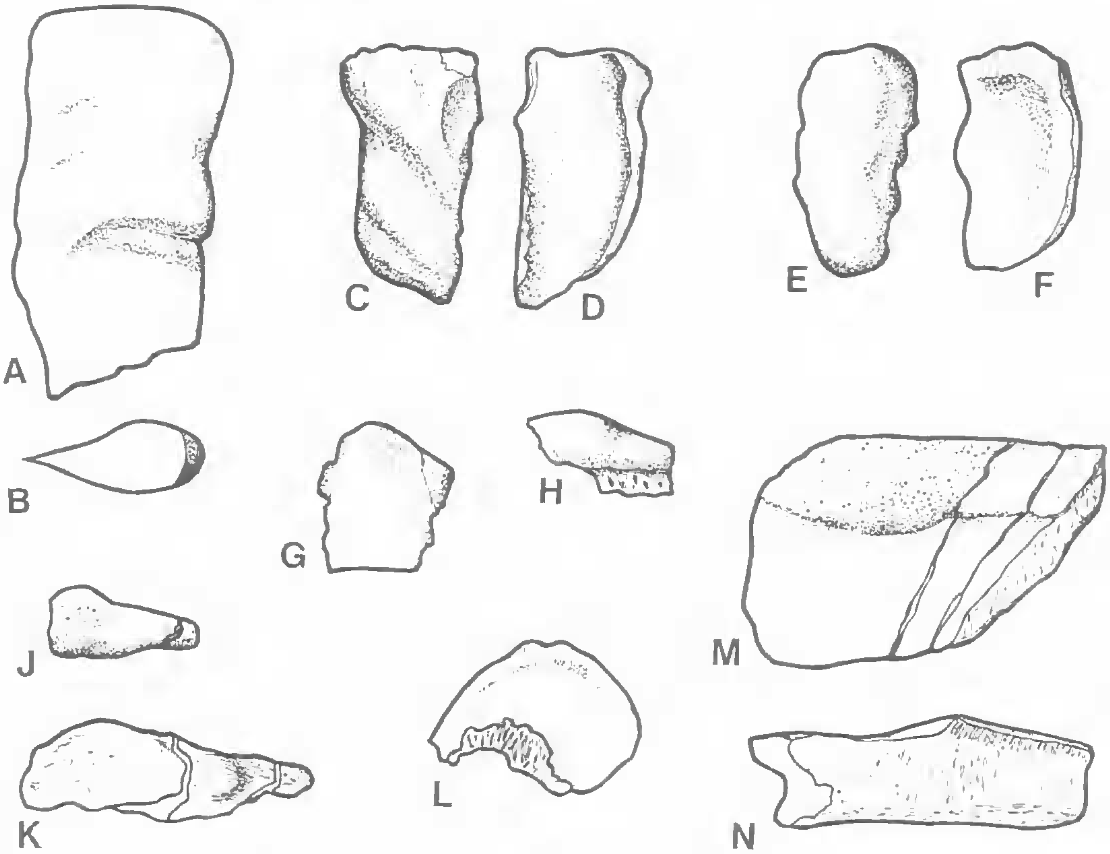

FIG. 2. Sketches of teeth from the Lower Carboniferous of Rockhampton. A. Deltoptychiid gen. et sp. indet. QM F809, crown view showing undulations, approximately X 3; B. Cross-section shape of tooth QM F809, approximately X 3; C. *Deltoptychius* sp. UQ F76061, crown view, approximately X 5.5; D. UQ F76061, ventral view, approximately X 5.5; E. Cochliodont gen. et sp. indet., UQ F6063, crown view, approximately X 5; F. UQ F76063, ventral view, approximately X 5; G. *Psephodus?* sp. indet., UQ F76054, crown view, approximately X 1.5; H. Helodont gen. et sp. indet., UQ F6055, lingual view, approximately X 3.5; J. Helodont?, UQ F76062a, crown view, approximately X 7; K. Helodont?, UQ F76062b, crown view, approximately X 14; L. Petalodont gen. et sp. indet., UQ F76060, lingual view, approximately X 6; M. *Psammodus* sp., UQ F76064, crown and lingual view, approximately X 1; N. UQ F76064, cross-section of tooth showing general histological structure, approximately X 1.

Deltodus is a correct one, but in the unsatisfactory state of our antiopodean scientific libraries, I am unable to make a more exact determination. If a species of this genus, it approaches *D. aliformis* McCoy, but is much more regular in outline, and lacks the contracted posterior end of that species" (in Jack & Etheridge, 1892, p. 296). In fact the specimen exhibits no characteristics of the genus *Deltodus*, being too abraded to allow generic identification or even to be certain to which group of "bradyodont" teeth it might belong. From its overall size and rectangular shape it might be a helodont or deltoptychiid tooth. The presence of three indistinct diagonal undulations across the crown suggests that QM F809 belongs to the latter family.

NEW MATERIAL

TOURNAISIAN GUDMAN OOLITE

Psephodus? sp. indet.
Fig. 1G

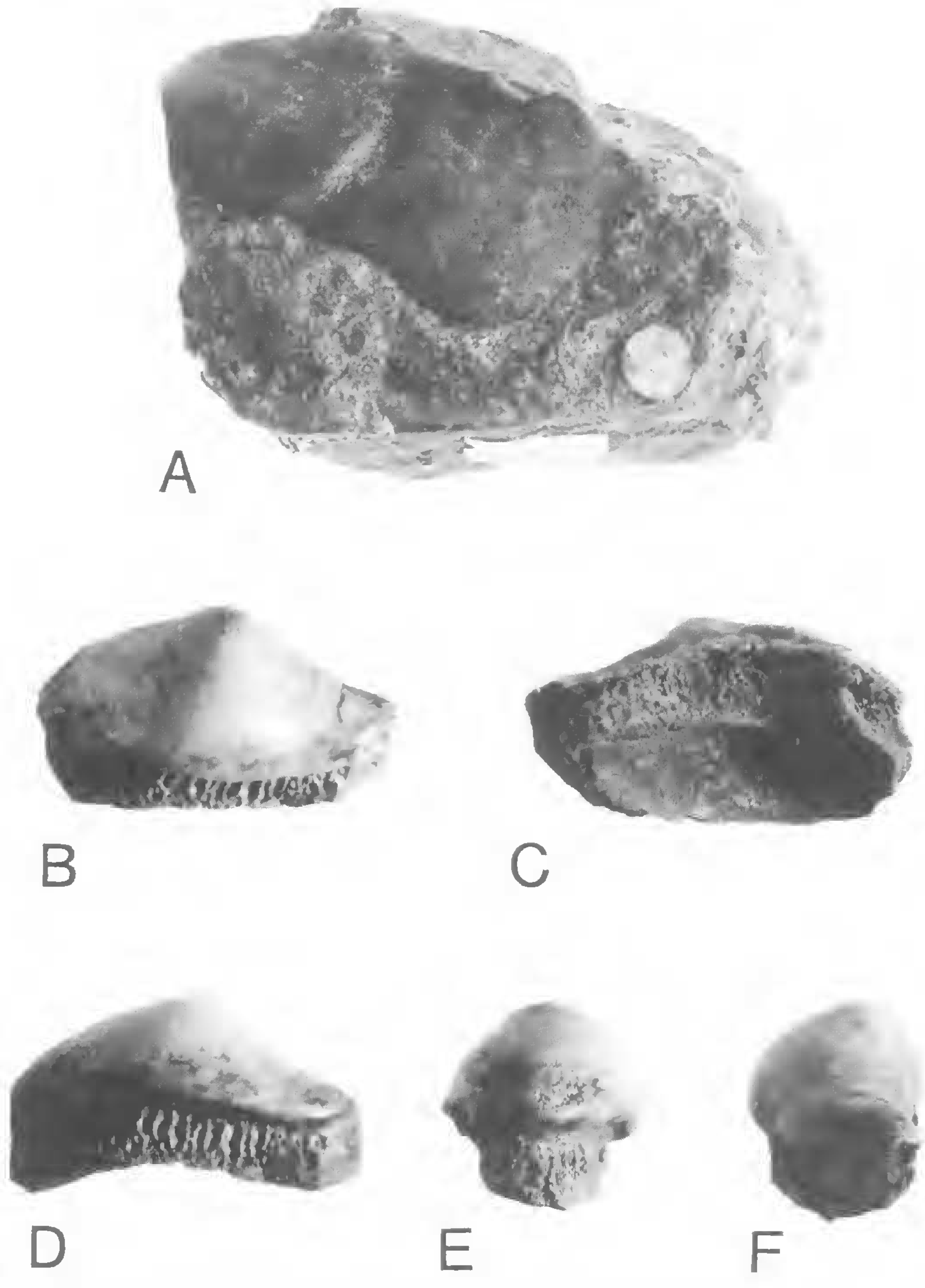

FIG. 1A. QM F809, deltoptychiid gen. et sp. indet. Lower Carboniferous, Rockhampton Group. Collected by Charles Walter de Vis. Dorsal view of crown; approximately X 2. B-D. UQ F76059, *Helodus* sp. Lower Carboniferous, Visean, Rockhampton Group, Lion Creek Limestone B. Dorsal (occlusal) view of tooth; C. Ventral view of base; D. Presumed lingual view showing foramina; E. Lateral view; F. Lateral view. All X 2.

MATERIAL

University of Queensland Geology Department (UQ) F 76053-54. UQ F 76053 is from L4890 (GW20) — on crest of second hill W of Malchi Nine-Mile Road, W of Lower Gracemere Lagoon — Ridgelands 1:100.000 (RI) 333.100; UQ F 76054 is from L4901 (GW23) — on eastern edge of crest of fourth hill W of Malchi Nine-Mile Road, W of Lower Gracemere Lagoon — RI 328.093.

MEASUREMENTS

Tooth UQ F 76053 has a crown measuring about 31 by 20 by 8.5 mm. Tooth UQ F 76054 is broken around the rim and slightly compressed, with shatter cracks across the crown. The tootb measures about 21.5 by 19 by 7 mm.

REMARKS

These teeth have gently rounded crowns which appear to be broader at one end. They are almost certainly cochliodont teeth and are tentatively referred to the genus *Psephodus* Agassiz (1859 ms.; St John & Worthen, 1883). This bradyodont genus is one of the earliest to occur in the Early Carboniferous of the U.S.A. (St John & Worthen, 1883). Teeth which might belong to this genus have been found in the Late Devonian of Western Australia (J.A. Long, pers. comm.), and Obruchev (1962) also recorded similar psephodont teeth in the Early Carboniferous of Kuzbas.

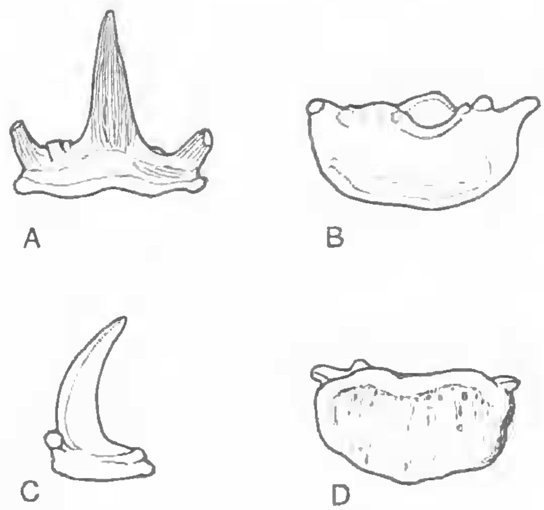

FIG. 3. UQ F76056, *Stethacanthus* sp. Lower Carboniferous, Visean, Rockhampton Group, Malchi Formation A. Labial view; B, Dorsal view; C. Lateral view; D. Basal view. Sketches all approximately X 4.

The Queensland teeth closely resemble the tooth forms called *Psephodus obliquus* and *P. placentus* St John and Worthen (1883) from the Tournaisian Kinderhook Formation (upper fish bed) of Iowa.

Helodont gen. et sp. indet.
Fig. 1H

MATERIAL

UQ F 76055 from L4899 (GW21) — on a crest of third hill W of Malchi Nine-Mile Road, W of Lower Gracemere Lagoon — RI 329095.

MEASUREMENTS

About 10 mm along the occlusal rim (broken at one end) and about 5 mm deep.

REMARKS

This tooth has an elongate rounded crown with a central raised area. There is a narrow neck groove, and the remains of the base show several large lingual foramina. This tooth could possibly be referred to the genus *Helodus* but until more material is available will be left indeterminate.

VISEAN MALCHI FORMATION

Stethacanthus sp. indet.
Figs 3A-D

MATERIAL

UQ F 76056 from L5014 (GW30 — limestone about 1.2 km SW of Granville Homestead, 80 m S of Limestone Creek, RI 242198; unnamed limestone, below Cargoogie Oolite Member.

DESCRIPTION AND MEASUREMENTS

The D-shaped basal surface of tooth UQ F 76056 is 15 mm by 7 mm. It has a marked labial lip behind which is a concave area with fine foramina arranged along the lee of the labial rim and set in shallow grooves within the concavity. The fine grooves and ridges cross the base to the lingual rim (Fig. 3D). The height of the main cusp above the labial base-cusp interface is 10 mm. There are about 10 strong striations on the labial surface of the cusp, and these curve proximally towards the midline of the cusp (Fig. 3A). There are strong lateral ribs on the main cusp, which curves gently backwards at an angle of about 20° (Fig. 3C). The two lateral cusps are directed outwards, with intermediate cusps represented by broken bases between these and the main cusp (Figs 3A, B). Two intermediate cusps are seen on the left labial side and three on the right (Fig. 3B).

REMARKS

This stethacanthid tooth is similar to that called '*Cladodus*' *thomusi* by Turner (1982a) found in the Early Carboniferous of Western Australia and north Queensland. The previously described specimens may now be referred to the genus *Stethacanthus* Newbery 1889 because of the configuration of the labial rim and lingual shelf on the base. The new tooth apparently has a small number of lateral cusps, four or less, and a deep D-shaped base. It resembles cladodont teeth including the form called *Cladodus ferox* Newberry and Worthen (1866) from the St Louis Limestone (Early Visean) of the U.S.A.

Cladodont fam., gen. et sp. indet.
Figs 4A-D

MATERIAL

UQ F 76057 from L4986 (GW36) — limestone outcrop RC2 E of Black Jin Creek, 500 m S of main Ridgelands-Rockhampton Road, R1270199; unnamed limestone, below Cargoogie Oolite Member.

DESCRIPTION AND MEASUREMENTS

Tooth UQ F 76057 has an elongate D-shaped base, 33 mm long by 10 mm across (Fig. 4B). There is a shallow D-shaped depression in the centre of the basal surface. Some fine foramina and thin grooves can be seen on the lingual basal surface. The lingual shelf on this specimen is quite narrow, with no prominent bosses, and the lingual border is gently undulated (Fig. 3D). There is a narrow labial basal shelf, 2 mm high. The central cusp is at least 20 mm high and the apex is missing. The surface is finely striated with distinct lateral ribs; there are 18-20 fine striations on the labial surface, some of which bifurcate towards the base of the cusp. The proximal striations curve away from the mid-line of the central cusp. Strong horizontal striations can be seen below the main cusp on the left labial side of the tooth (Fig. 4A). The main cusp curves back at an angle of about 60° (Fig. 4C). There are two lateral cusps at either end of the tooth directed outwards and backwards. There was probably at least one pair of smaller intermediate cusps, one of which is still represented by its base (Fig. 4d). The area between is too badly-preserved to provide the full cusp count.

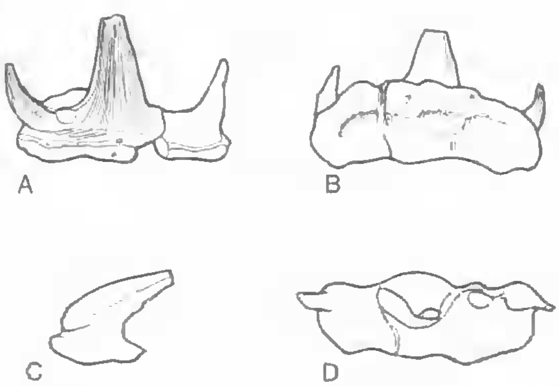

FIG. 4. UQ F76057 cladodont gen. et sp. indet. Lower Carboniferous, Visean, Rockhampton Group, Malchi Formation A. Labial view; B. Dorsal view; C. Lateral view; D. Basal view. Sketches all approximately X 3.

REMARKS

This tooth does not belong to *Stethacanthus* but might be from either a ctenacanth or perhaps the stethacanthid *Symmorium*.

Psephodus?

MATERIAL

UQ F 76065 from limestone RA1 (GWF-3M), WSW of Rockhampton, 18.1m above base of limestone at base of small ridge 100 m N of road, W of three-way junction near Deep Creek, approximately 1 km SE of Limestone Creek — L4988; unnamed limestone, Malchi Formation, Rockhampton Group; Visean.

DESCRIPTION AND MEASUREMENTS

Broken pieces of tooth about 10 mm square by 1 mm deep. Smooth crown surface with a slightly concave basal surface.

Bradyodont indet.

MATERIAL

UQ F 76058 from L5014 (GW30.2) — about 1.6 km SW of Granville Homestead, 80 m S of Limestone Creek (see above); unnamed limestone, Rockhampton Group.

REMARKS AND MEASUREMENTS

A small piece of crown, possibly psephodont, 7 mm by 10 mm.

LION CREEK LIMESTONE

Helodus sp.
Figs 1B-F

MATERIAL

UQ F 76059 from a crinoidal limestone (presumed to be from the Lion Creek Limestone), western end of outcrop 1 km NNE of Hillrose Homestead, 4-5 km ESE of Dalma township, near Rockhampton — L5421. The block was found in talus and not *in situ*.

DESCRIPTION AND MEASUREMENTS

The tooth is large, about 25 mm long by 10 mm labio-lingually and 15 mm deep. The crown of the tooth, the constricted neck and part of the labial base were exposed.

The crown (Figs 1B, D-F) is pitted evenly with fine pores, and is rounded in all directions with a strongly rounded and raised mid-portion, which is slightly skewed to one side. In cross-section, or in side view (Figs 1E, F), the crown is slightly concave on the labial surface and more strongly convex on the lingual surface. The crown-base interface is a narrow groove-like neck. The base itself is smaller than the crown, with an elongate D-shaped outline, and extends in the presumed lingual and downward direction. It has a maximum depth of about 5 mm (Fig. 1E). The presumed lingual surface on the base is perforated by a row of large foramina below which are smaller indentations and foramina (Fig. 1D). There are at least 22 coarse ribs separating the foramina (Fig. 1D). There are no clear foramina on the labial surface of the base, rather a concave trough passes down to the basal surface, which is itself slightly concave (Fig. 1C).

REMARKS

The tooth is nearest in form to those referred to *Helodus*. Most species referred to this genus are known only from teeth and teeth from a single dentition are so variable that if they were found separately they would be referred to different genera. Sadly, the teeth of one species known from articulated material, *Helodus simplex* Ag., are not well-known (e.g. Patterson 1965). There are many isolated teeth figured in the literature; Woodward in his 1889 Catalogue listed 48 species. Obruchev (1964) described a typical helodont dentition as comprising transversely elongated teeth in eight to nine series of four or five teeth in each half-jaw; the teeth in the middle (fourth and fifth series) are the largest and usually fuse into plates. As it is difficult, therefore, to orient an isolated tooth I have had to assume the lingual and labial directions.

Helodont teeth have been reported mainly from the Early Carboniferous of the U.S.A., Canada, Britain, France, Belgium and the U.S.S.R. as well as Australia (e.g. Turner 1982a). Teeth referred to the genus *Helodus* have been reported from the Late Devonian of the U.S.A.; the status of these teeth needs to be reviewed. *Helodus* teeth of different species have also been described from the Late Carboniferous and Early Permian of the U.S.A. (e.g. Woodward 1889) and from the Early Permian of Australia (Teichert 1943) and the Urals (e.g. Obruchev 1964). The Queensland tooth is very similar in size and shape to one figured by Obruchev (1962) and referred to the species *Helodus derjawini* of Tolmatchev 1924. This form occurs in the Tournaisian of the Kuznets Basin.

Petalodont gen. et sp. indet.
Fig. 2L

MATERIAL

UQ F 76060 from (GW6) WSW of Rockhampton, — first massive limestone near base of formation; Grid 8951 Ridgelands KV 194.120 — L4936.

DESCRIPTION AND MEASUREMENTS

The tooth is about 9 mm at widest by 6 mm at deepest with an intact occusal surface and rim and a broken basal rim. Crown with slightly convex labial and slightly concave lingual surface. Occlusal rim of crown strongly rounded with a medial pair of rounded denticulations rising a short way above the rim. Faint striations on the lingual occlusal rim. The basal roots apparently absent. The hard tissue of the crown is clearly shown on the broken basal surface; the structure is highly cancellous.

REMARKS

This presumed petalodont tooth, the first record for Australia, might be placed in the genus *Antliodus* or *Tanaodus*. Both genera were recently reviewed by Hansen (1985), and both are restricted to the Early Carboniferous.

Deltoptychius sp.
Figs 2C, D

MATERIAL

UQ F 76061 from GW6 WSW of Rockhampton, — first massive limestone near base of formation; Grid 8951 Ridgelands KV 194.120 — L4936.

DESCRIPTION AND MEASUREMENTS

The tooth measures 14 mm on the longest edge. The crown is subrectangular with a wider extension at one end. Three gentle undulations cross the crown surface at an angle of about 60° to the long axis. The basal surface is gently concave.

Helodont?
Figs 2J, K

MATERIAL

UQ F 76062 a,b from GWA-11, WSW of Rockhampton, limestone approximately 5 m above L4936 but further east; Grid 8951 Ridgelands KV 203.121 — L4968.

DESCRIPTION AND MEASUREMENTS

Both teeth are about 5 mm along broken occlusal length. One small elongate tooth with a central rounded dome (Fig. 2J); broken and worn with a central, slightly-raised dome and ridges of dentine separated by the bony tissue of the base (Fig. 2K).

REMARKS

These two small teeth were extracted together from the same small piece of rock. It is possible that both belonged to the same dentition and thus they have been considered together.

Cochliodont gen. et sp. indet.
Figs 2E, F

MATERIAL

UQ F 76063 from GW14 WSW of Rockhampton, — L4955 from near the top, limestone talus near large bioherm on southern flank of limestone ridge approximately 1 km NE of Hillrose Homestead; Grid — Ridgelands R1 198.177.

DESCRIPTION AND MEASUREMENTS

The toothplate measures 10 by 5 by 3 mm at greatest depth. The high crown is strongly arched with the highest point to the front of the crown (Fig. 2E). Some asymmetry with a steeper angle on the right side. Rim lightly inrolled on the right antero-lateral and opposite postero-lateral margins (Fig. 2F). The base is concave.

Psammodus sp.
Fig. 2M, N

MATERIAL

UQ F 76064 from GW16 the main limestone WSW of Rockhampton, in low-lying area immediately east and south of bend in road, 400 m N of Hillrose Homestead. Grid — Ridgelands R1 194.114 — L4981.

DESCRIPTION AND MEASUREMENTS

Crown surface about 80 by 25 mm. Depth of tooth about 20 mm. Lingual extension of base about 30 mm across. Large tooth with a well-worn flattened rectangular crown on a bony base with a lingual extension at an angle of about 45° (Fig. 2M). There is a marked step between the crown and lingual base. The broken cross-section shows the gross details of the histology (Fig. 2N); a thin upper layer of tubular dentine about 4 mm deep sits on a layer of more spongy tissue about 12-13 mm deep. The basal layer is a laminar bony tissue about 3 mm deep.

PALAEOECOLOGY

The oolitic and pisolitic limestones and the arenaceous limestones of the Rockhampton Group are thought to have been formed in high-energy environments along the shoreline bordering the eastern edge of the Connors-Auburn Volcanic Arc (Day *et al.*, 1983). They were laid down on shallow banks in the narrow, unstable continental Yarrol Shelf where the Calliope Island Arc might still have been emergent in places (Day *et al.*, 1983). Most of the vertebrate specimens have been found as isolated, and often well-worn or broken, teeth. The slow-growing tooth plates of the 'bradyodont' fish probably dropped to the seabed when the fish died, not necessarily near the life habitat, and might then have been rolled around in the swash forming the oolites. The cladodont teeth, however, are reasonably fresh and unbroken. These sharks probably lost their deciduous teeth by accidental breakage fairly near to the point of internment. No microfauna has been found in the high-energy limestones to date.

ACKNOWLEDGEMENTS

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